

WHAT IS CLAIMED IS:

1. An apparatus for estimating a road condition for use in a vehicle having steering control means for actuating a device mechanically independent of a manually operated steering member to steer each wheel, comprising:

reaction torque detection means for detecting a reaction torque when at least a wheel of said vehicle is steered by said steering control means;

aligning torque estimation means for estimating an aligning torque produced on said wheel on the basis of the reaction torque detected by said reaction torque detection means;

wheel factor providing means for providing at least one of wheel factors including a side force and a slip angle applied to said wheel; and

grip factor estimation means for estimating a grip factor of at least a tire of said wheel, in accordance with a relationship between the aligning torque estimated by said aligning torque estimation means and the wheel factor provided by said wheel factor providing means.

2. An apparatus for estimating a road condition as set forth in claim 1, further comprising;

reference aligning torque setting means for setting a reference aligning torque on the basis of the wheel factor provided by said wheel factor providing means and the aligning torque estimated by said aligning torque estimation means,

wherein said grip factor estimation means estimates the grip factor of said tire on the basis of a result of comparison between the aligning torque estimated by said aligning torque estimation means and the reference aligning torque set by said reference aligning torque setting means.

3. An apparatus for estimating a road condition as set forth in claim 2, wherein said reference aligning torque setting means sets the reference aligning torque by approximating a characteristic of the aligning torque estimated by said aligning torque estimation means against the wheel factor provided by said wheel factor providing means to a linear characteristic of the reference aligning torque including at least the origin, and sets the reference aligning torque on the basis of the linear characteristic of the reference aligning torque.

4. An apparatus for estimating a road condition as set forth in claim 2, wherein said reference aligning torque setting means sets a linear characteristic of the reference aligning torque with a gradient which is provided by a brush model of said wheel, and sets the reference aligning torque on the basis of the linear characteristic of the reference aligning torque.

5. An apparatus for estimating a road condition as set forth in claim 1, further comprising;

friction estimation means for estimating a coefficient of friction of a road on which said vehicle is running, on the basis of the grip factor estimated by said

grip factor estimation means.

6. An apparatus for estimating a road condition as set forth in claim 5, further comprising;

warning means for warning to a vehicle driver when at least one of road factors including the grip factor estimated by said grip factor estimation means and the coefficient of friction estimated by said friction estimation means is less than a predetermined value.

7. An apparatus for estimating a road condition as set forth in claim 5, further comprising;

road surface determination means for determining whether said vehicle is running on a split road with at least two parallel lanes having different coefficients of friction, on the basis of the result of comparison between at least one of road factors including the grip factor estimated by said grip factor estimation means and the coefficient of friction estimated by said friction estimation means with respect to a right wheel of said vehicle, and at least one of said road factors with respect to a left wheel of said vehicle.

8. A vehicle motion control apparatus provided with an apparatus for estimating a road condition for use in a vehicle having steering control means for actuating a device mechanically independent of a manually operated steering member to steer each wheel, comprising:

reaction torque detection means for detecting a reaction torque when at least a wheel of said vehicle is

steered by said steering control means;

aligning torque estimation means for estimating an aligning torque produced on said wheel on the basis of the reaction torque detected by said reaction torque detection means;

wheel factor providing means for providing at least one of wheel factors including a side force and a slip angle applied to said wheel; and

grip factor estimation means for estimating a grip factor of at least a tire of said wheel, in accordance with a relationship between the aligning torque estimated by said aligning torque estimation means and the wheel factor provided by said wheel factor providing means,

wherein said steering control means steers said wheel to provide a steering angle thereof on the basis of the grip factor estimated by said grip factor estimation means.

9. A vehicle motion control apparatus as set forth in claim 8, further comprising;

friction estimation means for estimating a coefficient of friction of a road on which said vehicle is running, on the basis of the grip factor estimated by said grip factor estimation means, wherein said steering control means steers said wheel to provide a steering angle thereof on the basis of at least one of road factors including the grip factor estimated by said grip factor estimation means and the coefficient of friction estimated by said friction

estimation means.

10. A vehicle motion control apparatus as set forth in claim 8, wherein said steering control means steers one wheel of said vehicle with the grip factor reduced to be less than a predetermined value, to reduce the steering angle of said one wheel.

11. A vehicle motion control apparatus as set forth in claim 10, wherein said steering control means steers the other one wheel of said vehicle placed on a position opposite to said one wheel in a lateral direction of said vehicle, to increase the steering angle of the other one wheel.

12. A vehicle motion control apparatus as set forth in claim 8, further comprising;

braking force control means for controlling a braking force applied to each wheel of said vehicle, said braking force control means setting said braking force on the basis of the grip factor estimated by said grip factor estimation means.

13. A vehicle motion control apparatus as set forth in claim 12, wherein when the grip factor of one wheel of said vehicle estimated by said grip factor estimation means is reduced to be less than a predetermined value, said braking force control means applies the braking force to wheels of said vehicle other than said one wheel.

14. A vehicle motion control apparatus as set forth in claim 12, wherein when the grip factor of one wheel of said

vehicle estimated by said grip factor estimation means is reduced to be less than a predetermined value during the braking operation of said vehicle, said braking force control means reduces the braking force applied to said one wheel.

15. A vehicle motion control apparatus as set forth in claim 14, wherein when said braking force control means reduces the braking force applied to said one wheel, said braking force control means increases the braking force applied to at least one of the wheels of said vehicle other than said one wheel.

16. A vehicle motion control apparatus as set forth in claim 8, further comprising;

reference aligning torque setting means for setting a reference aligning torque on the basis of the wheel factor provided by said wheel factor providing means and the aligning torque estimated by said aligning torque estimation means,

wherein said grip factor estimation means estimates the grip factor of said tire on the basis of a result of comparison between the aligning torque estimated by said aligning torque estimation means and the reference aligning torque set by said reference aligning torque setting means.

17. A vehicle motion control apparatus as set forth in claim 16, wherein said reference aligning torque setting means sets the reference aligning torque by approximating a characteristic of the aligning torque estimated by said

aligning torque estimation means against the wheel factor provided by said wheel factor providing means to a linear characteristic of the reference aligning torque including at least the origin, and sets the reference aligning torque on the basis of the linear characteristic of the reference aligning torque.

18. A vehicle motion control apparatus as set forth in claim 17, wherein said reference aligning torque setting means sets a linear characteristic of the reference aligning torque with a gradient which is provided by a brush model of said wheel, and sets the reference aligning torque on the basis of the linear characteristic of the reference aligning torque.